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# SLOW RATE INFILTRATION LAND TREATMENT AND RECIRCULATION OF LANDFILL LEACHATE IN ONTARIO

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## 1.0 Introduction

This extended abstract reports on progress made up to the approximate mid-way point of this three-year research study (M.O.E. project no. RAC-333). Emphasis will be placed on two specific studies being undertaken in this multi-faceted, interdisciplinary project; that is vegetative and soil microbial response to MSW leachate exposure. The vegetative response data presented here originate from the Muskoka Lakes landfill near Port Carling, Ontario (McBride et al., 1988), whereas the soil microbial response data were collected at the Hamilton-Wentworth regional landfill in Glanbrook Township. In all, four leachate sources are being used for various experiments in this study, and Table 1 provides information on certain chemical constituents of each. A full screening of organic contaminants is also being carried out in collaboration with the Canada Centre for Inland Waters in Burlington, Ontario.

Table 1. Chemical composition of four landfill leachates under investigation.

| Chemical Constituents* | Landfill Site | | | |
|---|---|---|---|---|
| | Muskoka | Glanbrook | Leamington | Guelph |
| $NO_3$ | 0 | 0 | 0.34 | 0 |
| $NH_4$ | 103 | 12.5 | 360 | 865 |
| $PO_4$ | 0 | 0 | 0 | 1.38 |
| $SO_4$ | 0 | 258 | 10.0 | 49.4 |
| Cl | 98 | 1039 | 900 | 2464 |
| Mg | 32 | 594 | 90 | 580 |
| K | 114 | 406 | 483 | 1301 |
| Na | 41 | 580 | 373 | 1109 |
| Fe | 37.5 | 0.22 | 0.42 | 1.11 |
| Mn | 6.77 | 0 | 0.01 | 5.07 |
| Ni | 1.46 | 0 | 0 | 0.52 |
| Cd | 0.12 | 0.03 | 0.06 | 0.05 |
| Cu | 0 | 0 | 0 | 0 |
| Pb | 0 | 0 | 0 | 0 |
| Zn | 2.67 | 0.04 | 0.05 | 0.03 |
| TOC | 2446 | 447 | 216 | 3774 |
| pH | 5.44 | 7.45 | 7.65 | 7.01 |

* all chemical constituents are in units of $\mu g \bullet ml^{-1}$ with the exception of pH

2.0 <u>Vegetative Responses</u>

2.1 Preface

Research on vegetation at the Muskoka Lakes landfill site has been directed at aspects of forest decline and the stress ecophysiology of sugar maple (<u>Acer saccharum</u> Marsh) attributable to the leachate spray irrigation system operated by the municipality. Studies on the carbon dioxide and water vapour exchange rates of understory saplings and the spectral properties of their leaves have been undertaken in irrigated and unirrigated areas. The spectral properties of overstory leaves of mature trees pruned above the range of direct foliar contact have also been investigated in collaboration with researchers from the Ontario Centre for Remote Sensing (OMNR). Data from the 1987 and 1988 seasons are being analysed and some preliminary results are presented and discussed here.

2.2 Understory Photosynthesis and Transpiration

Daily spray application of leachate on the forest understory during the growing season deposits a residue on plant leaves to the point where the entire adaxial (upper) surface is irreversibly stained through to leaf senscence in the autumn. This precipitate has properties that may instigate changes in leaf energy budgets by altering the amount and characteristics of incident radiation in addition to possible direct phytotoxic effects or changes in leaf cell structure. The abaxial (lower) surfaces of the leaves, however, remain largely unstained, the leaves remain turgid and otherwise retain the outward integrity of unsprayed leaves throughout the growing season.

A LI-COR model LI-6000 portable photosynthesis system was employed to determine carbon dioxide and water vapour exchange rates and stomatal conductance. Measurable decreases in the stomatal conductance and photosynthetic rates of spray irrigated saplings were observed (Figure 1). Photosynthetic rates of spray irrigated saplings also decreased with increasing PAR irradiance (Figure 2) in contrast to the normal rise with irradiance demonstrated by the control saplings. The rate at which photosynthesis increased in response to higher stomatal conductance levels is also lower in irrigated saplings (Table 2) but appears to have improved over the two month sampling period in 1988. In contrast to these findings, transpiration rates of spray irrigated saplings did not deviate substantially and, in some cases, actually exceeded those measured in control saplings.

Many environmental parameters have an effect on stomatal conductance (e.g. relative humidity, irradiance, leaf and ambient air temperatures) and some of these factors have a direct effect on the photosynthetic process itself quite apart from the influence on $CO_2$ fixation through stomatal aperture response. The relative importance of any one parameter in controlling photosynthetic rates may be more easily discerned if viewed in terms of its inhibitory effect (i.e. photosynthetic limitation). This enables the partitioning of stomatal and non-stomatal limitations to photosynthesis (Jones, 1985). This approach has been applied to distinguish parameter limitations to photosynthesis in trees under differing environmental conditions (Teskey <u>et al</u>., 1986) and during rapid water stress



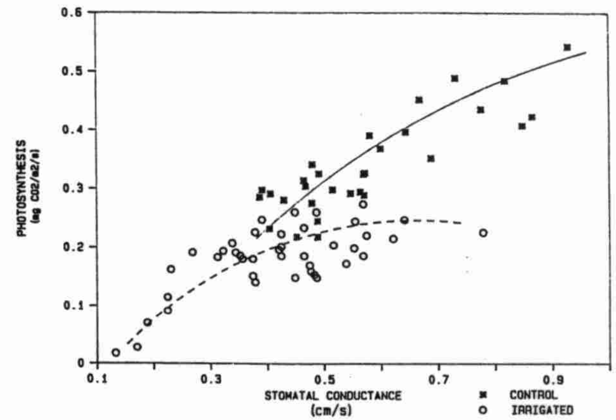


Figure 1. Rate of photosynthesis vs. stomatal conductance for leachate irrigated and unirrigated understory leaves of sugar maple at Muskoka Lakes (Aug. 31, 1988).

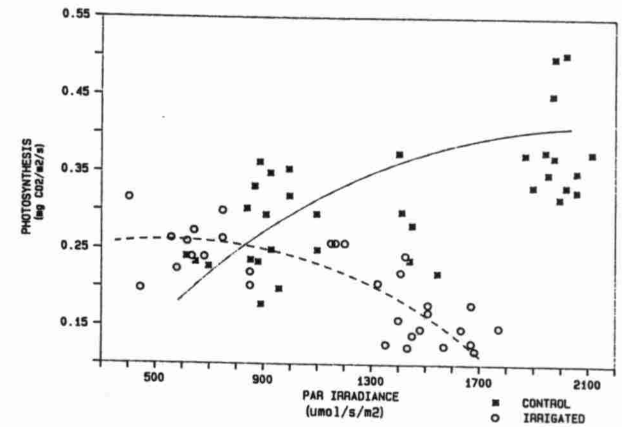


Figure 2. Rate of photosynthesis vs. incident photosynthetically-active radiation for leachate irrigated and unirrigated understory leaves of sugar maple at Muskoka Lakes (Aug. 16, 1988).

(Cornic et al., 1983). The lower rates of photosynthesis in spray irrigated saplings compared to those of control saplings at similar stomatal conductances (Figure 1) and the generally lower rates at which photosynthesis increases with larger stomatal apertures (Table 2) infer that the dominant photosynthetic limitations in operation may be non-stomatal in nature.

Table 2. Results from simple regression of photosynthetic rate ($mg\ CO_2 \bullet m^{-2} \bullet s^{-1}$) of sugar maple against the logarithm of stomatal conductance ($cm \bullet s^{-1}$) for three dates.

| Date | Treatment | Least Squares Parameter Coefficients* | |
|---|---|---|---|
| | | $b_0$ (intercept) | $b_1$ (slope) |
| July 6, 1988 | Control | 0.429 | 0.154 |
| | Irrigated | 0.254 | 0.081 |
| August 16, 1988 | Control | 0.432 | 0.153 |
| | Irrigated | 0.303 | 0.112 |
| August 30, 1988 | Control | 0.451 | 0.205 |
| | Irrigated | 0.316 | 0.144 |

* all regressions were significant at $P < 0.001$

Water use efficiency (WUE), the ratio of carbon dioxide assimilated to water lost, was lower in irrigated saplings over the sampling period (Table 3). However, the later measure of irrigated WUE exceeds that of the earlier season control measure made under abnormally severe water stress conditions.

Table 3. Water use efficiency of irrigated and unirrigated sugar maple for three dates.

| Date | Treatment | Water Use Efficiency |
|---|---|---|
| | | $mg\ CO_2 \bullet g^{-1} H_2O$ |
| July 6, 1988 | Control | 3.21 ± 0.05 |
| | Irrigated | 0.94 ± 0.37 |
| August 16, 1988 | Control | 6.64 ± 1.32 |
| | Irrigated | 0.87 ± 0.42 |
| August 30, 1988 | Control | 13.14 ± 1.50 |
| | Irrigated | 4.87 ± 0.68 |



2.3 Understory and Overstory Leaf Spectral Properties

The quality and quantity of spectral reflectance, transmittance and absorbance of light by leaves in the visible and near-infrared (400-1100 nm) wavelengths provide a basis for characterizing foliar structure and symptomatic interpretation of plant health (Gates et al., 1965; Horler et al., 1983). Spectral measurements on understory and overstory leaves were made with a LI-COR 1800 portable spectroradiometer fitted with an integrating sphere. Measurements of overstory leaves were also performed by O.C.R.S. personnel using a Spectron 590 spectroradiometer.

The control data for adaxial spectral reflectance of understory sugar maple (Figure 3) provide a typical pattern, with the characteristic green "thumbprint" at 540 nm (i.e. chlorophyll, nitrogen content), the "chlorophyll well" at 680 nm, and the "red edge and shoulder" at 700-1100 nm (i.e. indicator of stress, cell structure integrity, water content). At positions closer to the spray nozzles, the amount of leachate intercepted and the density of residue precipitated on the leaf surfaces increases, progressively altering the spectral reflectance. The reduced reflectance of the sprayed leaves in the red (700-1100 nm) waveband suggests a higher absorbance, possibly upsetting the normal leaf energy balance and leading to higher leaf temperatures. Spectral reflectance curves for understory abaxial leaf surfaces (Figure 4) are not as drastically altered and the decreased green reflectance (540 nm) is indicative of increased nitrogen and/or chlorophyll content (Hinzman et al., 1986; Shibayama and Akiyama, 1986).

The two instruments used in the spectral study of overstory leaves concurred well in general reflectance measurement. Reflectance patterns generated by the LI-COR 1800 for leaves of control and irrigated trees in July and August are presented in Figure 5. In July, virtually no differences in reflectance could be discerned, but similar spectra from August for irrigated trees demonstrate a decreased reflectance in the 540 nm range and increased reflectance in the red range. The "blue shift" of the red edge of reflectance that has been reported elsewhere (Horler et al., 1983; Rock et al., 1988) as being indicative of forest decline was not evident from overstory spectral measurements during the 1988 field season at Muskoka Lakes. This lends further support to the assertion that over-irrigation of leachates during abnormally wet seasons (e.g. 1986) is likely to be the most important factor contributing to the forest die-back observed at this landfill site (McBride et al., 1988).

## 3.0 Soil Microbial Responses

Two plot-scale installations (factorial, RCB experimental design) involving three irrigation methods (spray, trickle, subsurface for leachate, spray only for water) and three application rates (3.5, 7.0 and 14.0 $mm \bullet d^{-1}$) are operational at the Glanbrook landfill. A third is situated at the Essex County landfill #2 near Leamington.

Figure 6 shows a respresentative set of soil respiration data collected from the plots of the forested site at the Glanbrook landfill in 1988. The Glanbrook soils belong to the Smithville catena and are comprised of about 55% clay (dominantly clay mica/vermiculite, unbuffered C.E.C. 52 $cmol \bullet kg^{-1}$, specific surface 250 $m^2 \bullet g^{-1}$). The application of raw leachate to the forested plots significantly increased the measured soil respiration when compared to both the water irrigated plots and the environmental (rain-fed)

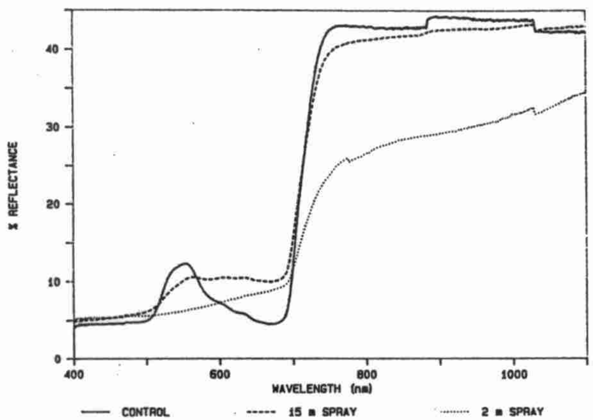


Figure 3. Spectral reflectance patterns for adaxial surfaces of leachate irrigated (variable intensity) and unirrigated understory leaves of sugar maple at Muskoka Lakes (Aug. 31, 1988).

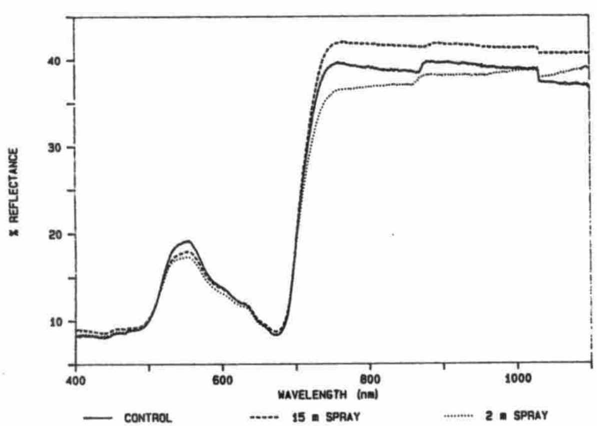


Figure 4. Spectral reflectance patterns for abaxial surfaces of leachate irrigated (variable intensity) and unirrigated understory leaves of sugar maple at Muskoka Lakes (Aug. 31, 1988).



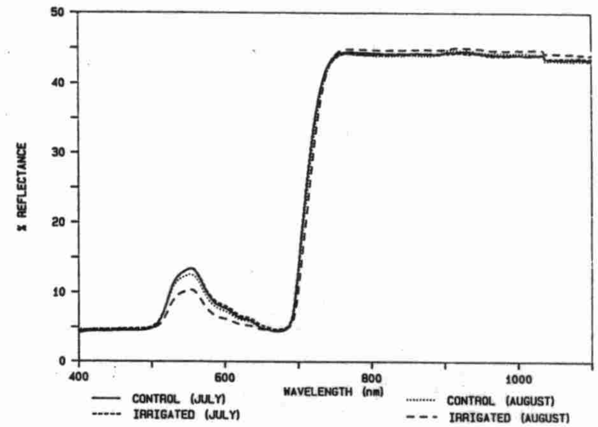


Figure 5. Spectral reflectance patterns for adaxial surfaces of overstory leaves of sugar maple trees situated within and outside of leachate irrigation areas at Muskoka Lakes (July 6 and Aug. 16, 1988).

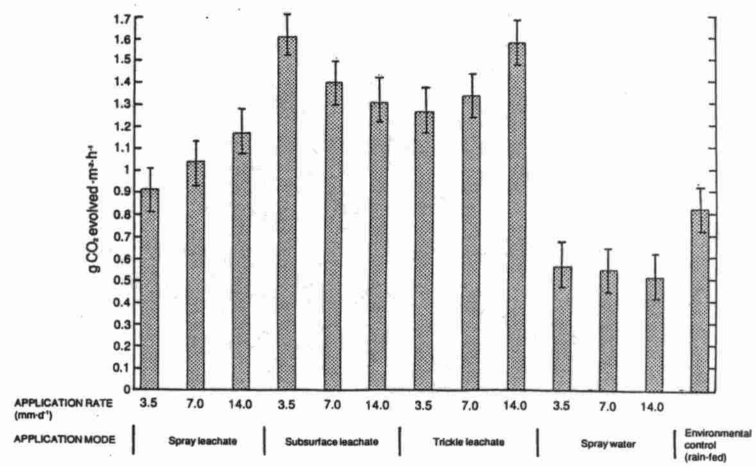


Figure 6. Rates of soil respiration on all treatment plots at the forested irrigation installation at the Glanbrook landfill (Aug. 31, 1988).

control ($P < 0.0001$). This analysis of variance takes both the rate and mode of irrigation into account. Soil respiration on plots receiving leachate by the spray method was significantly lower when compared to the trickle and subsurface leachate irrigation plots ($P < 0.0001$). For the trickle and spray leachate treatments, soil respiration tended to increase with the quantity of leachate applied while the opposing trend was observed in the subsurface irrigated plots. The application of water to the plots by spray irrigation significantly decreased soil respiration when compared to the environmental control ($P < 0.0001$).

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